Impact of different satellite radiance data sets using 3D-Var and hybrid variational/ EnKF data assimilation systems in the Rapid Refresh

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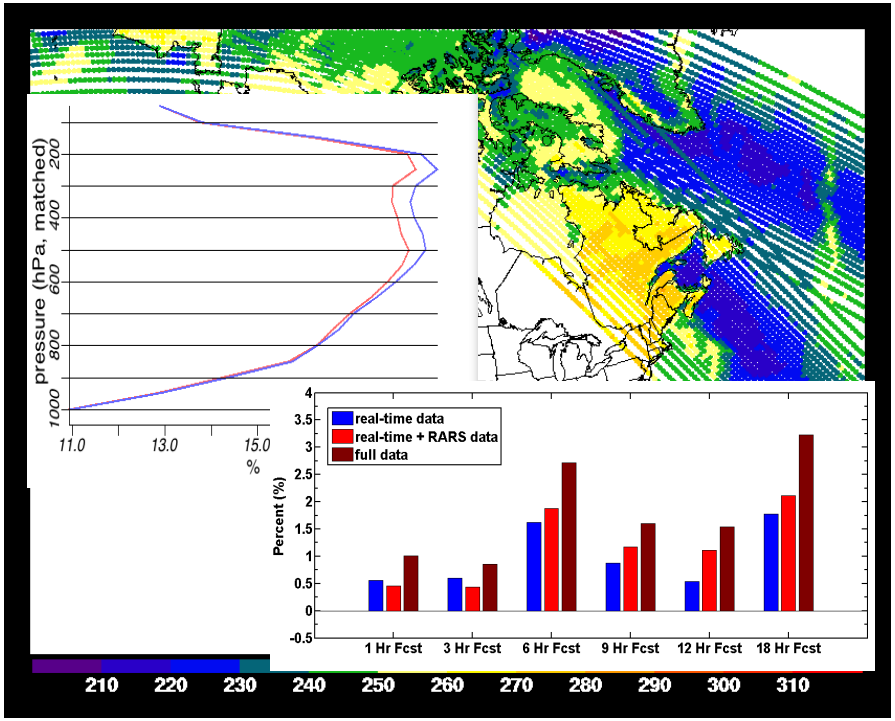


Presentation Outline

1. Background on Rapid Refresh (RAP) system
2. Data introduction and selected channels
3. Retrospective experiments
   - Hybrid EnKF RAP vs. 3D-Var RAP
   - Impact from different data latency:
     -- real-time
     -- RARS (Regional ATOVS Retransmission Services)
     -- Full coverage
   - AIRS and GOES data impact in hybrid RAP
4. 6-month real-time hybrid RAP parallel runs with and without radiance data
6. Summary and future work

Background on Rapid Refresh

NOAA/NCEP's hourly updated model

RAP version 1 -- NCEP since Spring 2012

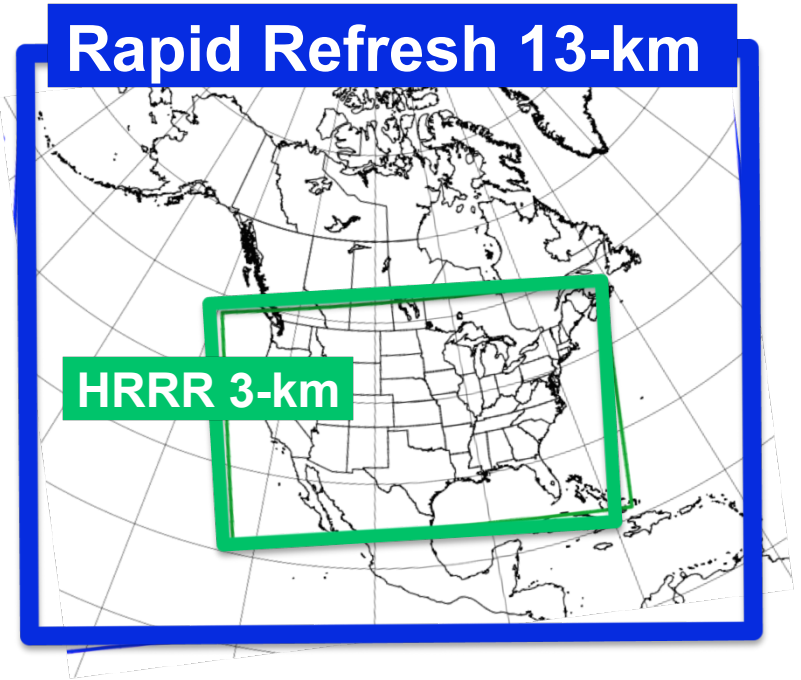
- Advanced community codes (ARW model, GSI analysis)
- Key features for short-range "situational awareness" application (cloud analysis, radar DFI assimilation)

➔ RAP guidance for aviation, severe weather, energy applications

RAP version 2 -- Planned NCEP 25 Feb. 2014

- DA enhancements (Hybrid – EnKF using global ensemble)
- Model enhancements (MYNN PBL, 9-layer LSM)

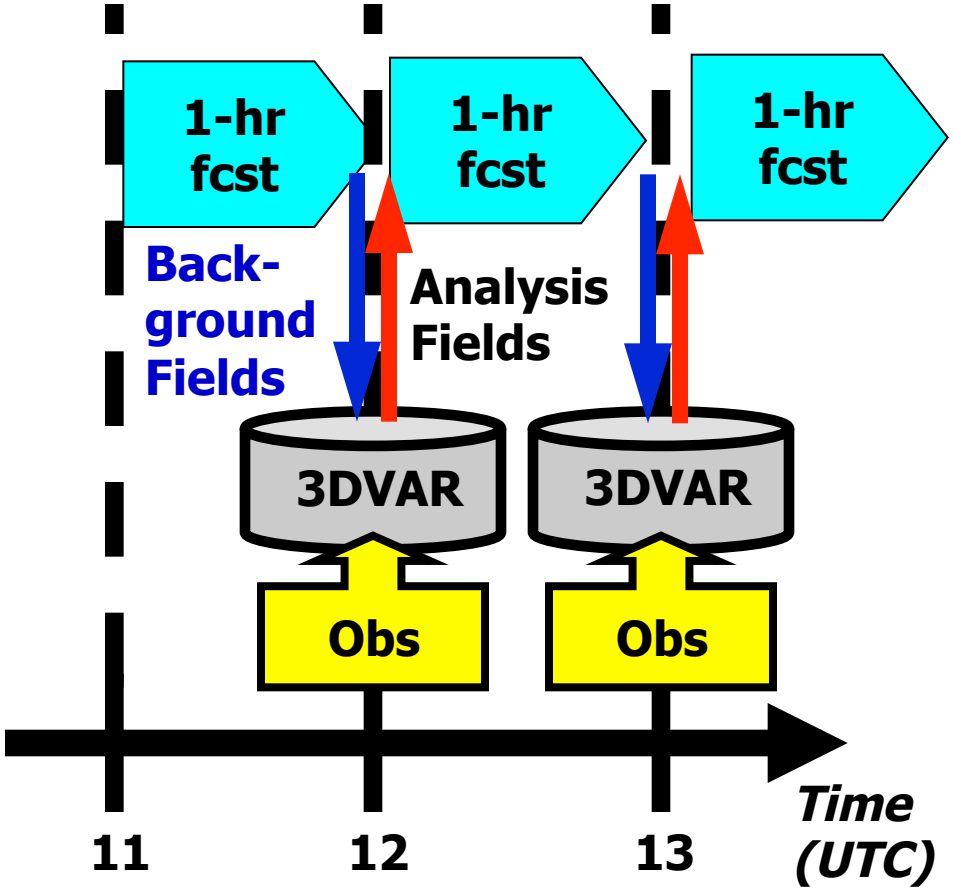
RAP version 3 -- under development



Rapid Refresh Hourly Update Cycle

Partial cycle atmospheric fields – introduce GFS information 2x per day

Fully cycle all land-sfc fields



Data types – counts/hr

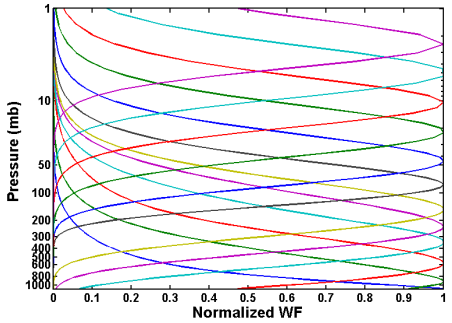
Rawinsonde (12h)	150
NOAA profilers	35
VAD winds	~130
PBL profilers / RASS	~25
Aircraft (V,T)	3500 – 10,000
METAR surface	2000 -2500
Mesonet (T,Td)	~8000
Mesonet (V)	~4000
Buoy / ship	200-400
GOES cloud winds	4000-8000
METAR cloud/vis/wx	~1800
GOES cloud-top P,T	10 km res.
Satellite radiances (AMSUA, HIRS, MHS)	
Radar reflectivity	1 km res.

Radiance Data

- **AMSU-A (Operationally used in RAP)**
  - Temperature information
  - Moisture information
- **HIRS4 (Operationally used in RAP)**
  - Temperature information
  - Moisture information (channels 10-12)
- **MHS (Operationally used in RAP)**
  - Moisture information
- **AIRS (not yet operationally used in RAP, testing data)**
  - High vertical resolution
  - Temperature and moisture information
- **GOES (not yet operationally used in RAP, testing data)**
  - Temperature and moisture information
  - Good hourly real-time coverage

Radiance Channels Selected for RAP

- **AMSU-A** (remove high-peaking channels)
  - metop-a: channels 1-6, 8-10, 15
  - noaa_n15: channels 1-10, 15
  - noaa_n18: channels 1-8, 10,15
  - noaa_n19: channels 1-7, 9-10,15

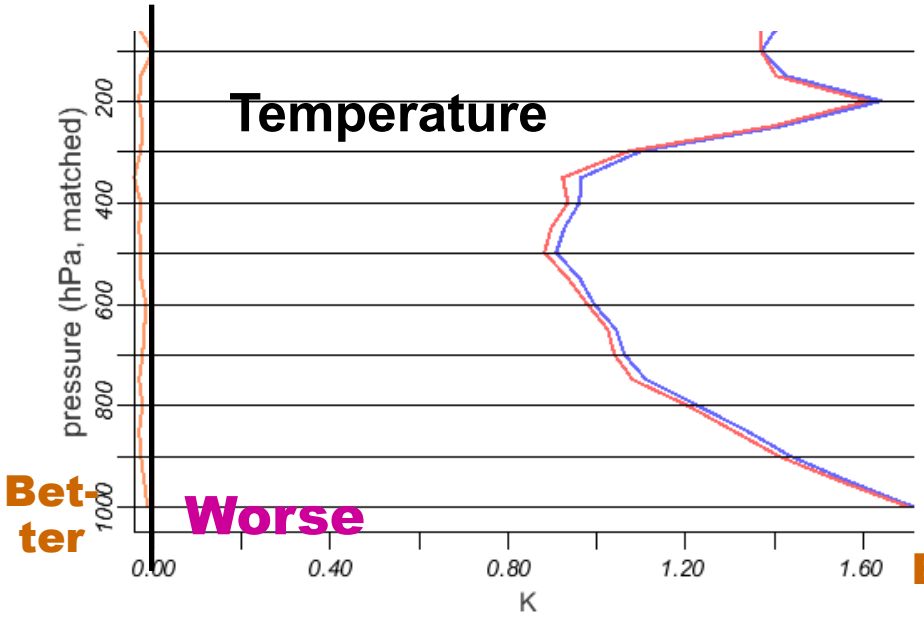


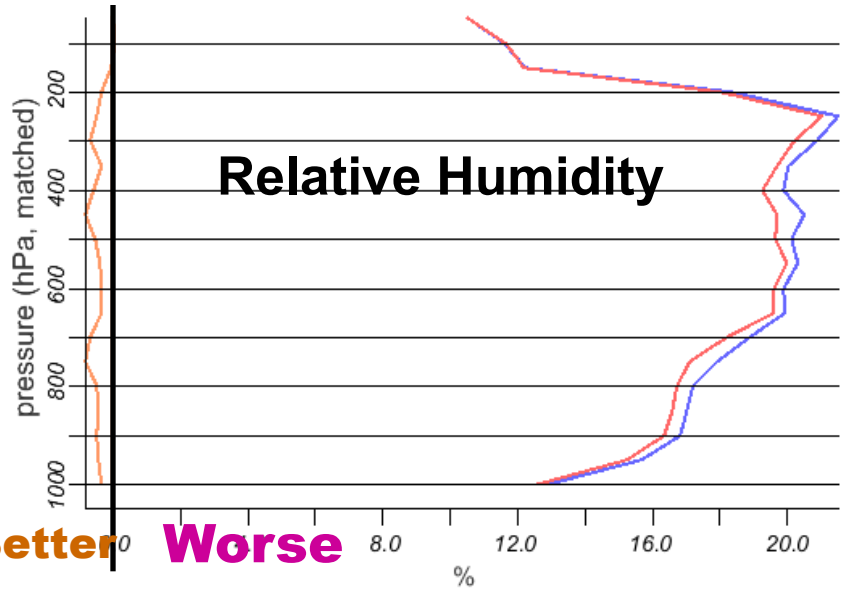
- **HIRS4** (remove high-peaking and ozone channels)
  - metop-a: channels: 4-8, 10-15
- **MHS** (remove high-peaking and ozone channels)
  - noaa_n18, metop-a: channels 1-5;
- **AIRS** (remove high-peaking channels)
  - Aqua: 68 channels selected from 120 GDAS channel set
- **GOES** (remove high-peaking channels)
  - GOES-15: channels 3-15

Retrospective Experiments
Set I: hybrid vs. 3D-Var

- **3D-Var**
  - 1-h cycling, 8-day retro run (May 28 – June 04 2012)
  - Conventional + radiance data (amsua/hirs4/mhs/goes)
- **Hybrid EnKF (RAP v2)**
  - **The same as 3D-Var run except using GSI hybrid EnKF (80 member global)**

6-h Forecast RMS Error (against raob)



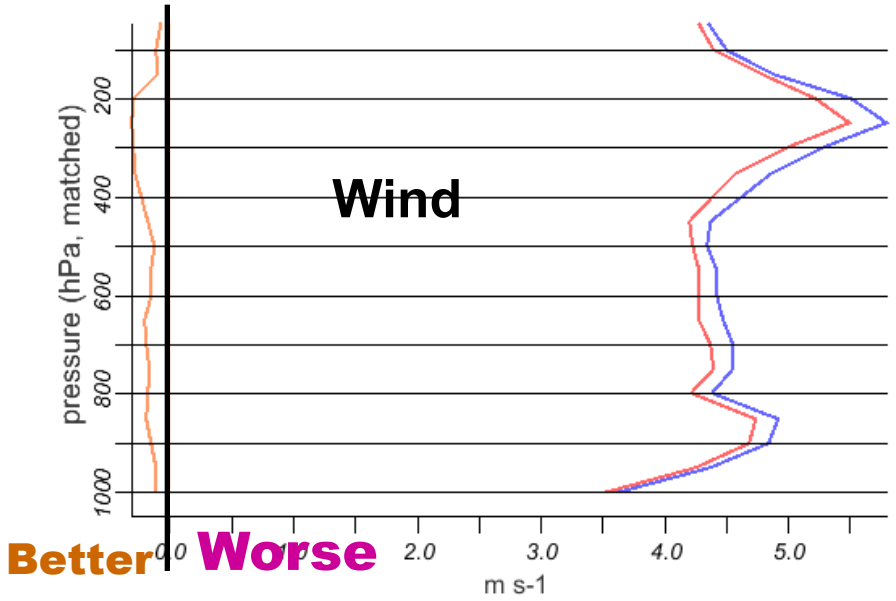


3D-Var

Hybrid EnKF (RAPv2)

upper-air verification

May28-June04 2012



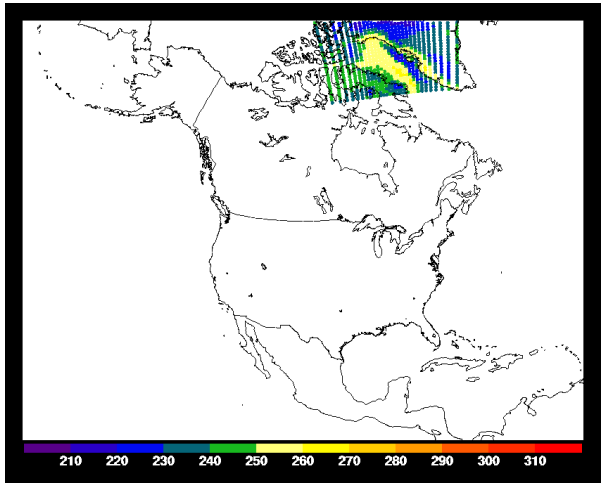
Retrospective Experiments Set II (different data files)

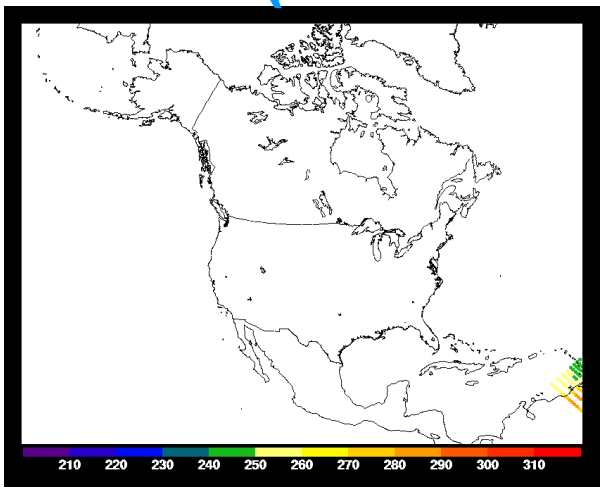
- **Extensive retro run for bias coefficients spin up**
- **Control run (CNTL) – (conventional data only)**
  - 1-h cycling run, 8-day retro run (May 28 – June 4 2012)
  - RAP Hybrid EnKF system
- **Real-time radiance (limited availability)**
  - CNTL + RAP real time radiance data (amsua/mhs/hirs4/goes)
  - Use updated bias coefficients from the extensive retro run
- **RARS + Real-time radiance (better availability)**

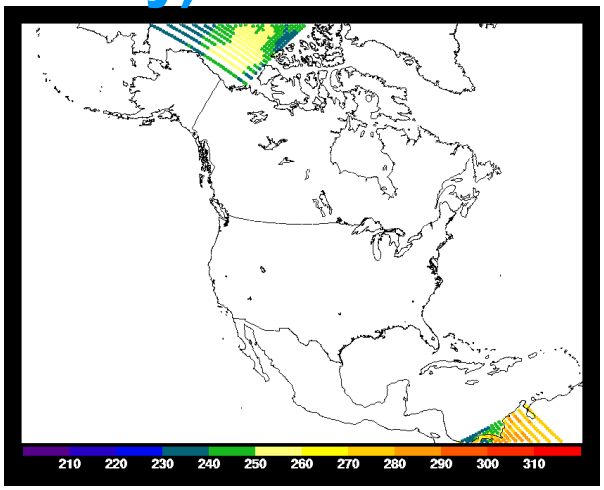
  (RARS = Regional ATOVS Retransmission Services)
- **Full coverage radiance (perfect availability)**
  - The same as experiment two but using full data for amsua/mhs/hirs4 (no data latency)

Coverage comparison for the RARS data and the regular feed data

Real-time radiance (limited availability)

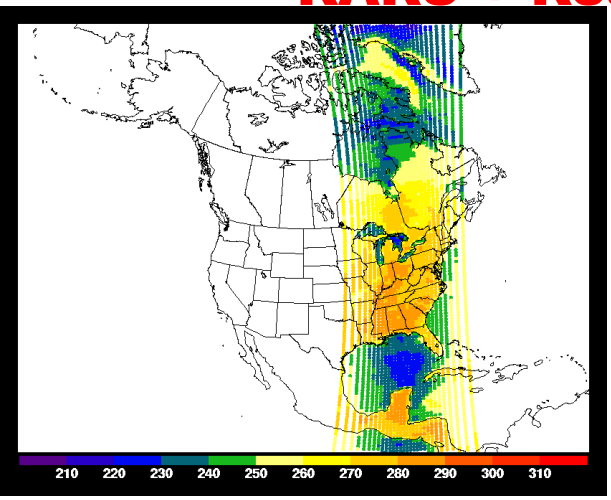




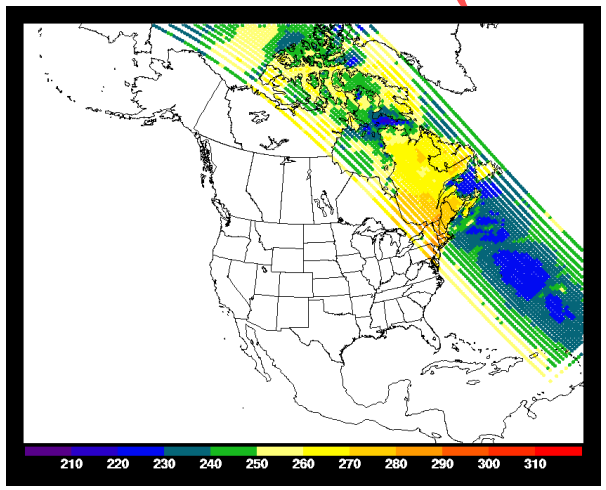


May 29 2012 amsua noaa-19

RARS + Real-time radiance (better availability)



08Z



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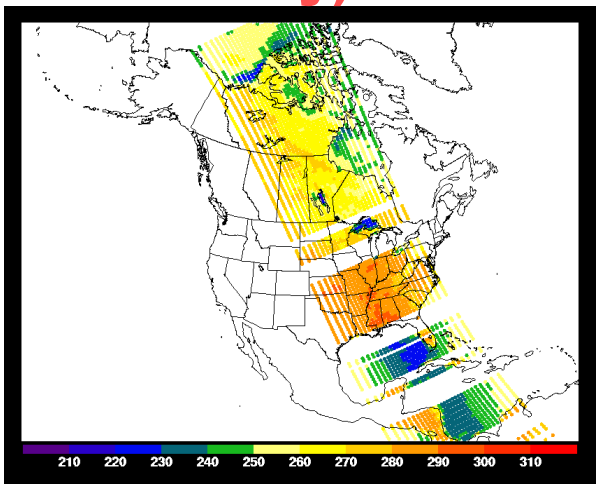
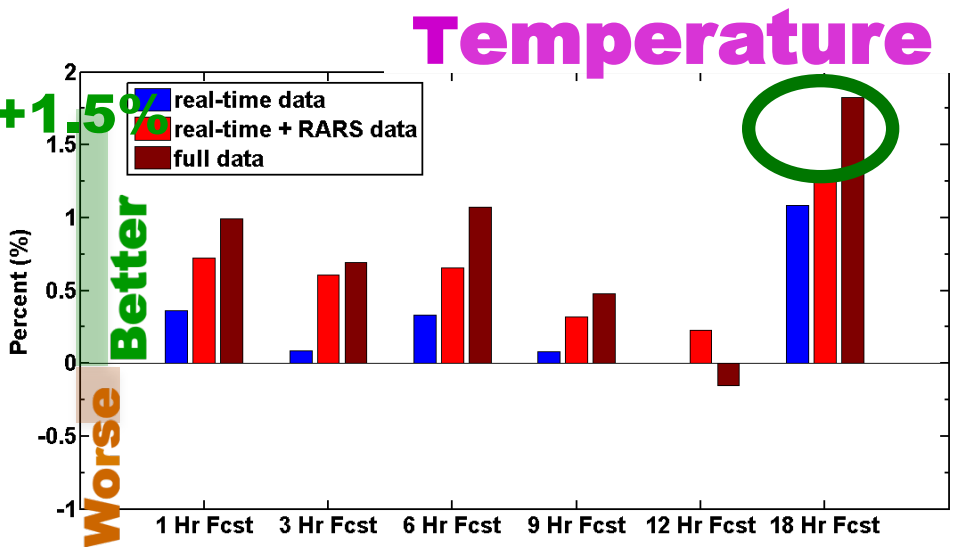
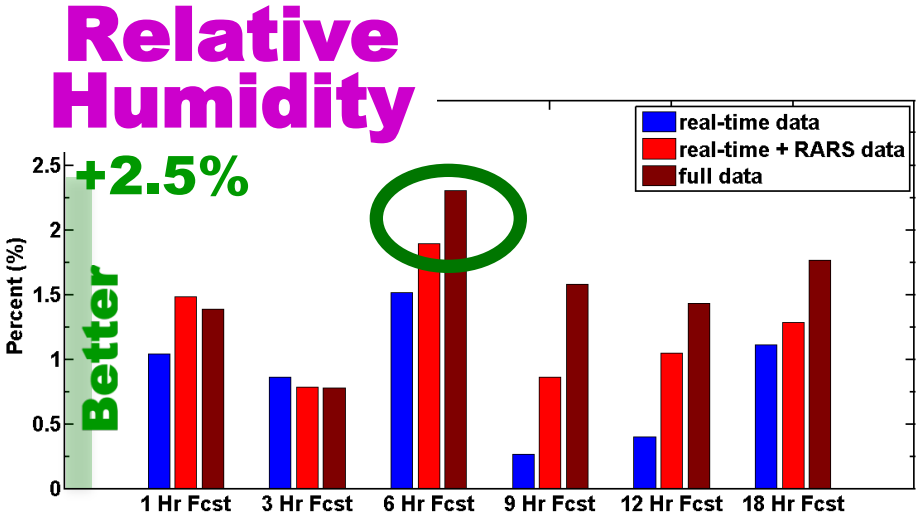


19Z

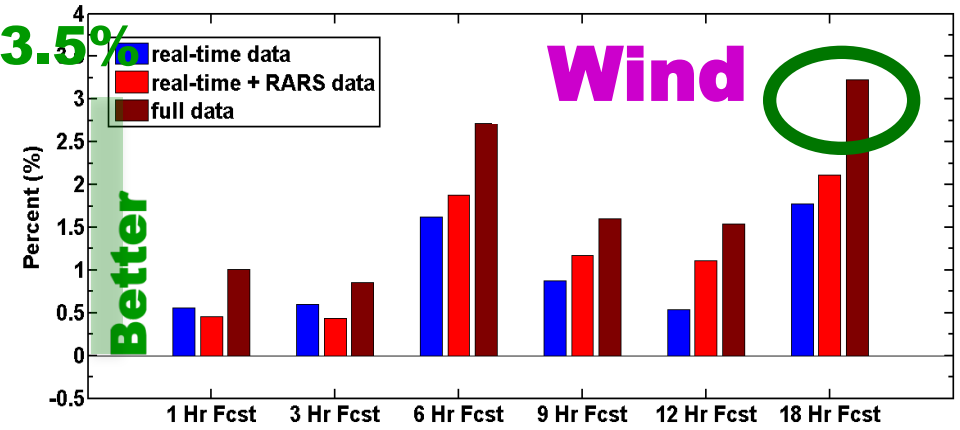
Impact from different data sets



18 Hr Fcst



6 Hr Fcst



18 Hr Fcst

Real-time data

RARS included

Full data

Normalize Errors

$$E_N = \frac{(CNTL - EXP)}{CNTL}$$

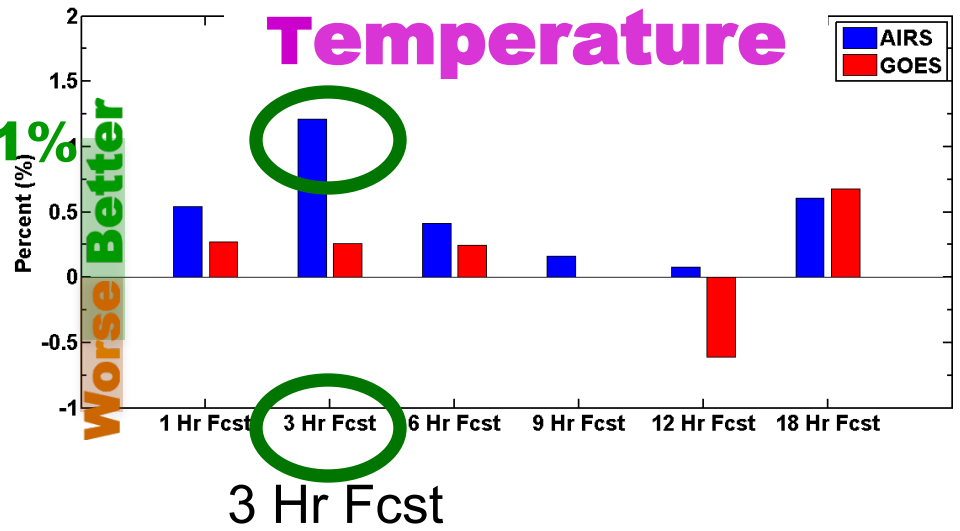
100-1000 hPa RMS mean

May28-June04 2012 retro runs

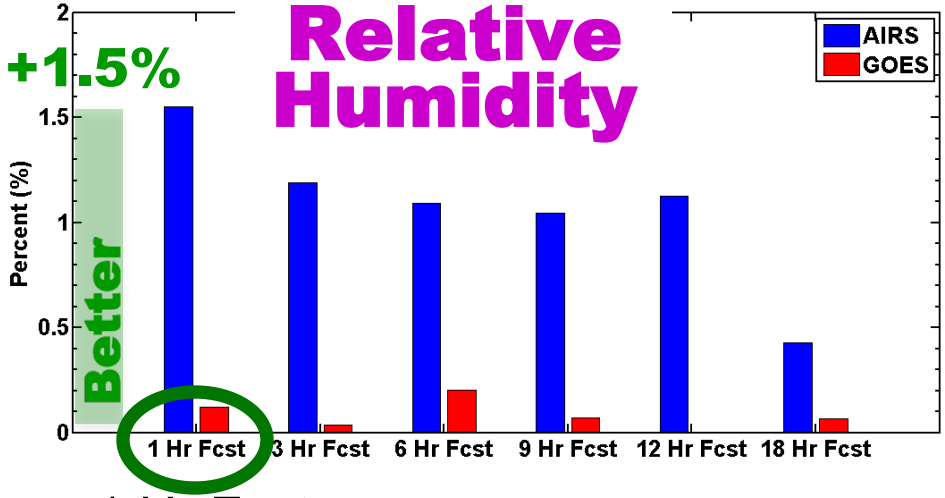
Retrospective Experiments
Set III: new sensors

- **Control run (CNTL) – Conventional data only**
  - 1-h cycling run, 8-day retro run (May 28 – June 4 2010)
  - Hybrid EnKF RAP system
- **AIRS radiance experiment**
  - CNTL + AIRS radiance data (no latency)
  - Using 68 selected channels for RAP
- **GOES radiance experiment**
  - CNTL + real time GOES 15 radiance data (sndr1,sndr2,sndr3, sndr4)

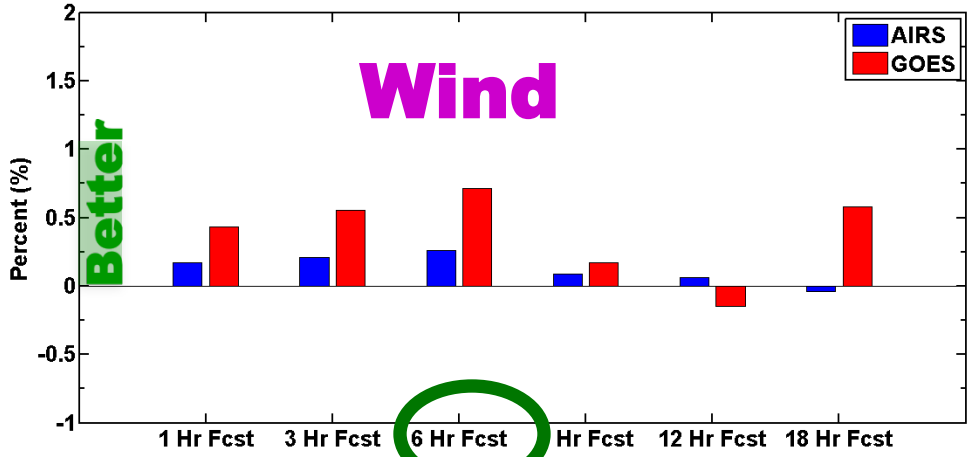
Impact from AIRS and GOES data (against raob 100-1000 hPa)



3 Hr Fcst



1 Hr Fcst



6 Hr Fcst

AIRS

GOES

Normalize Errors

$$E_N = \frac{(CNTL - EXP)}{CNTL}$$

100-1000 hPa RMS mean

May28-June04 2012

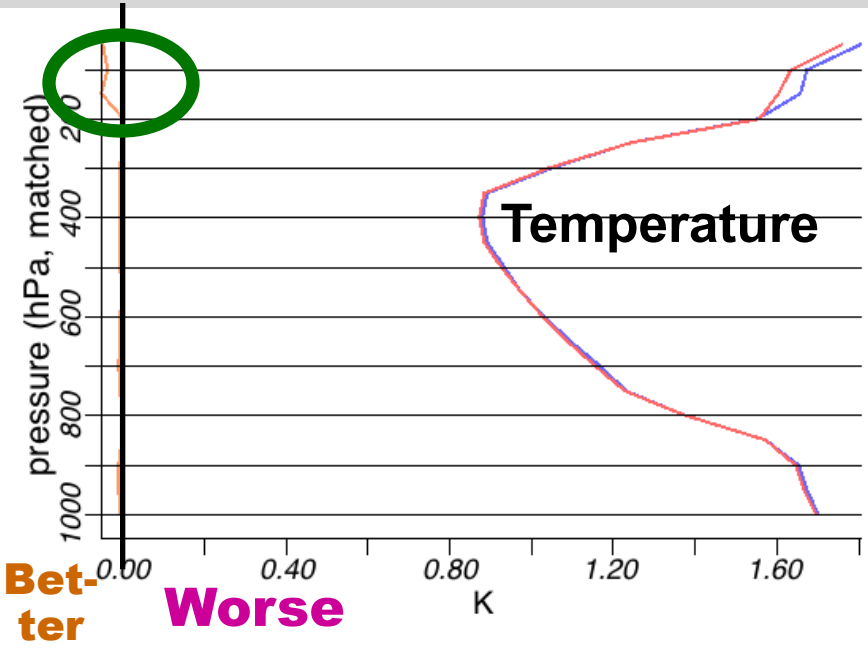
upper-air verification

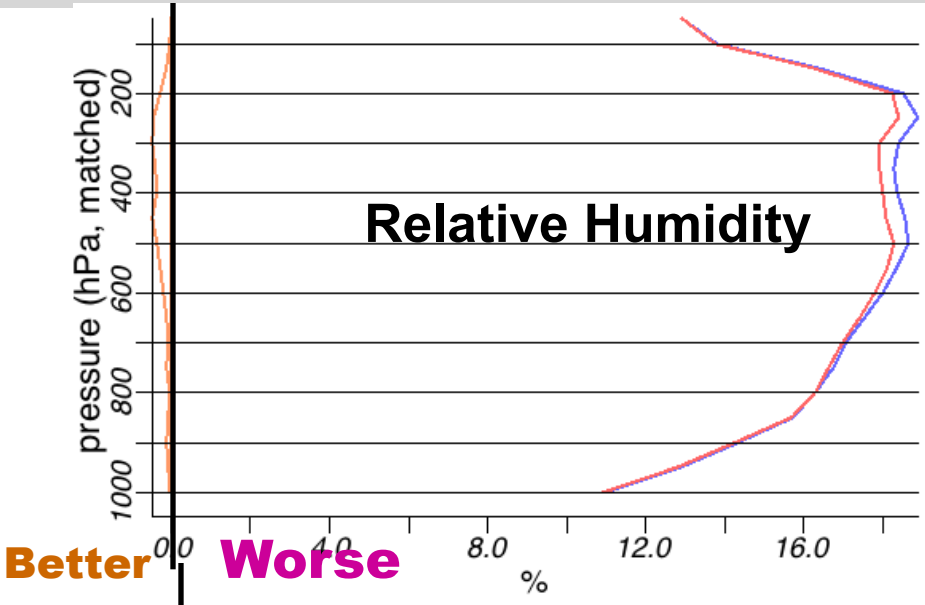
Real-time RAP Experiments

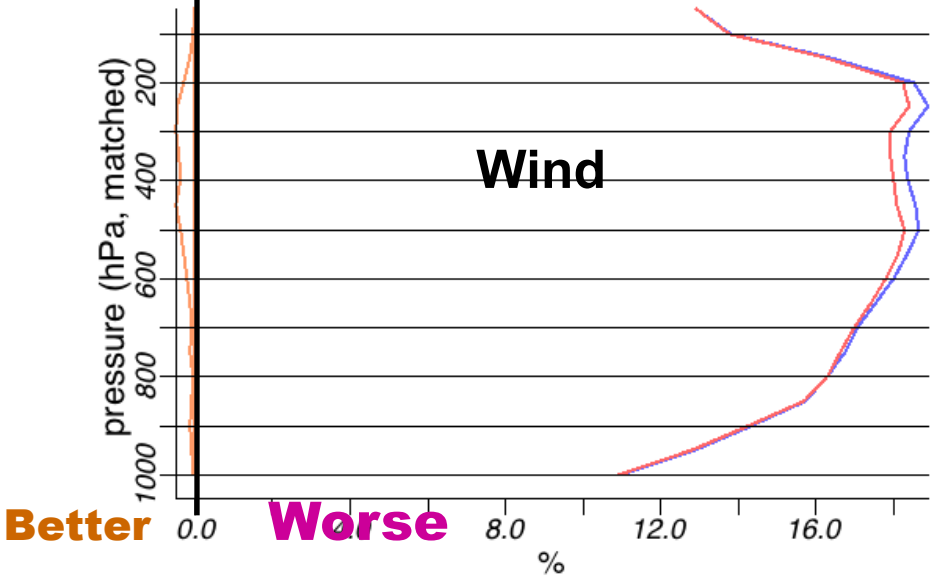
- **Real-time** RAP hybrid systems on Zeus:
  - 1-h cycling with partial cycle
  - real-time data
- **6 month time period**

  (Jun-July, Oct-Dec, 2013, Jan, 2014)
- **NO radiance**
  - conventional data only
- **WITH radiance**
  - conventional data + operational used radiance data (AMSU-A, HIRS4, MHS)

6-h Forecast RMS Error







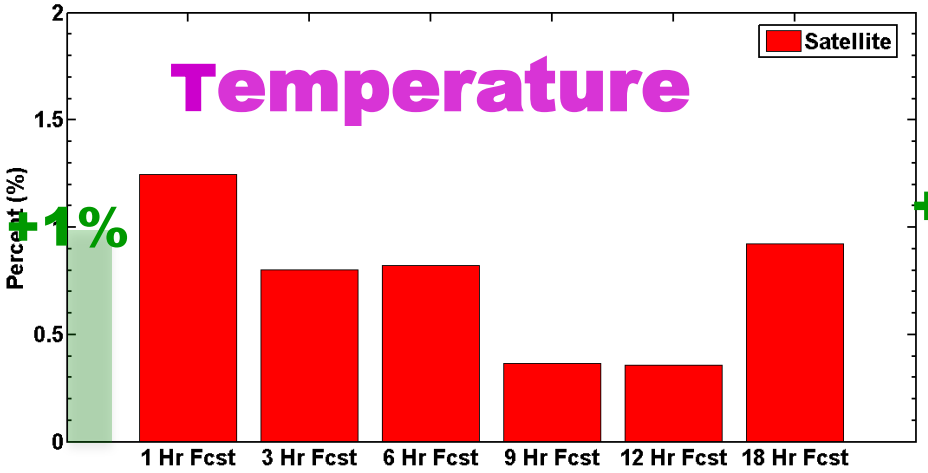
NO radiance

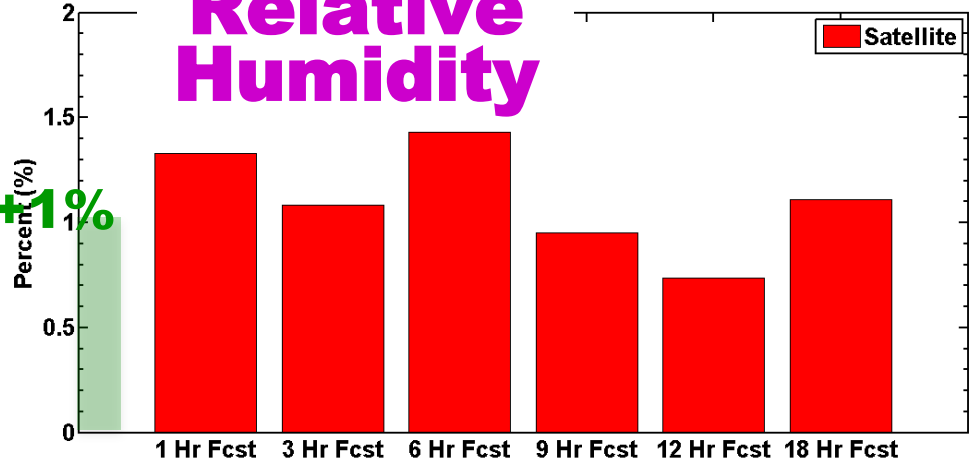
WITH radiance

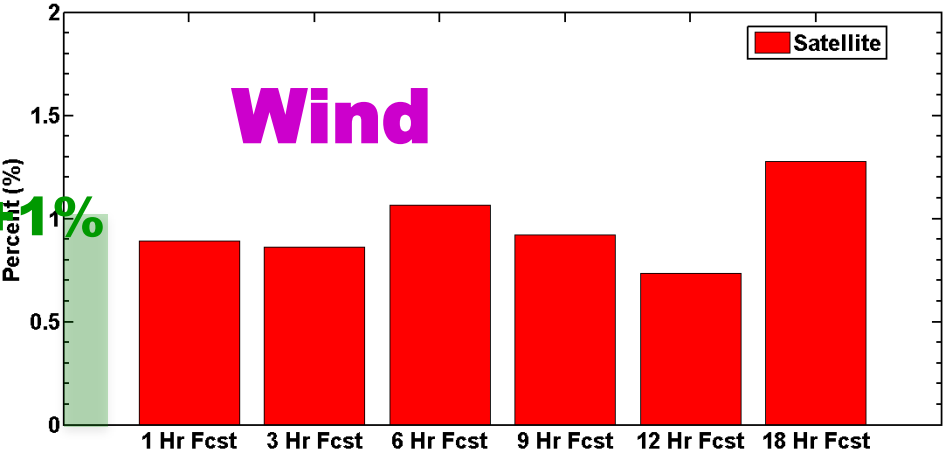
upper-air verification

6-month real-time runs averaged

% improvement from radiance DA







100-1000 hPa RMS mean

Normalize Errors

$$E_N = \frac{(CNTL - EXP)}{CNTL}$$

upper-air verification

6-month real-time runs averaged

Conclusions

- RAP EnKF hybrid run performed better than the 3D-Var RAP run including radiance data
- RAP real-time radiance data have slightly positive impact and the RARS data provide additional benefits
- AIRS and GOES data have slightly positive impact
- 6-month real time runs showed consistent positive impact (around 1%) from radiance data in RAP
- Recommendation for RAP v3 updates:
  - Include RARS data
  - Include AIRS and GOES sounding data

Upcoming and Future work

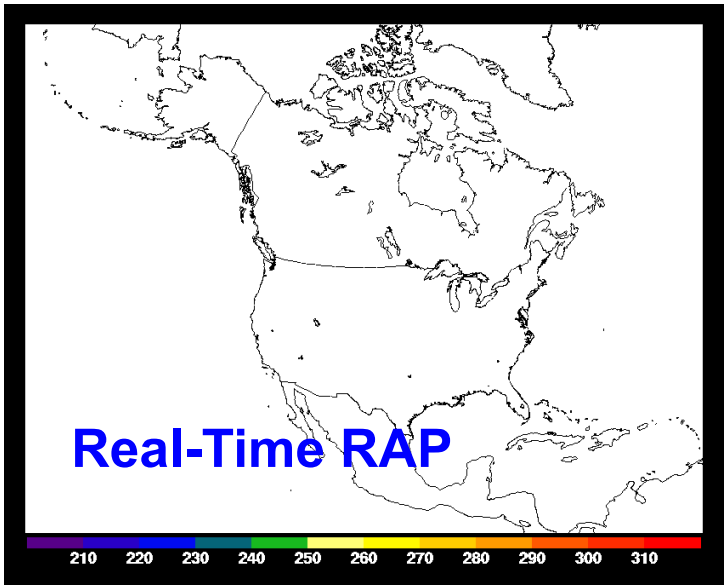
- Include the RARS data in RAP v3
- Include AIRS and GOES data in RAP v3
- Implement the enhanced radiance bias correction scheme (developed by EMC) in RAP
- Other new data

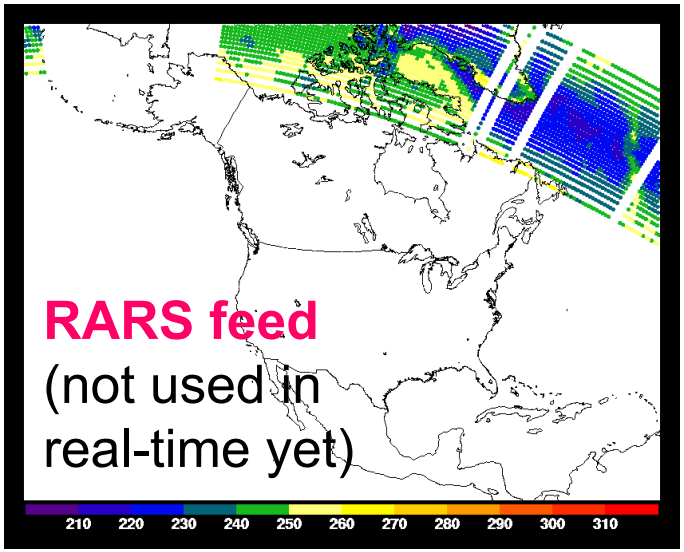
  -- ATMS and CrIS from NPP

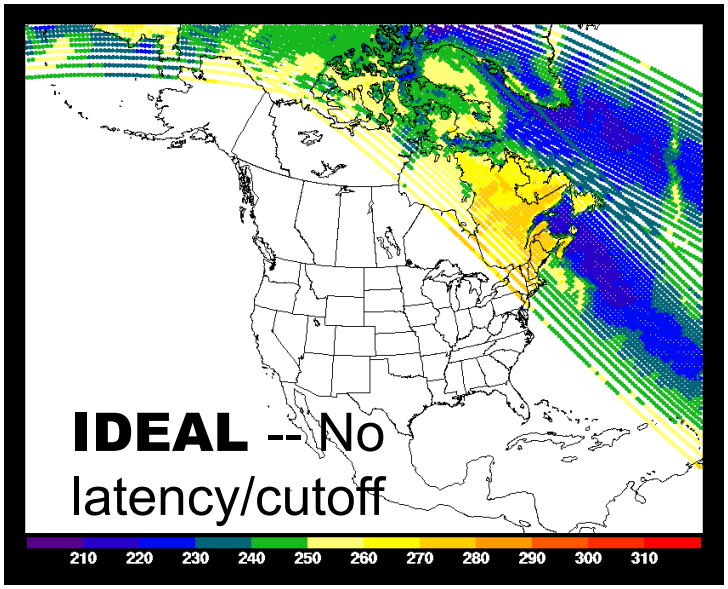
  -- IASI from metop-a/b

  - Increase RAP model top and model levels (for experiment and research purpose)
  - Real-time data latency problem: partial cycle strategy (more waiting time)

Real-Time Data Availability -- RARS





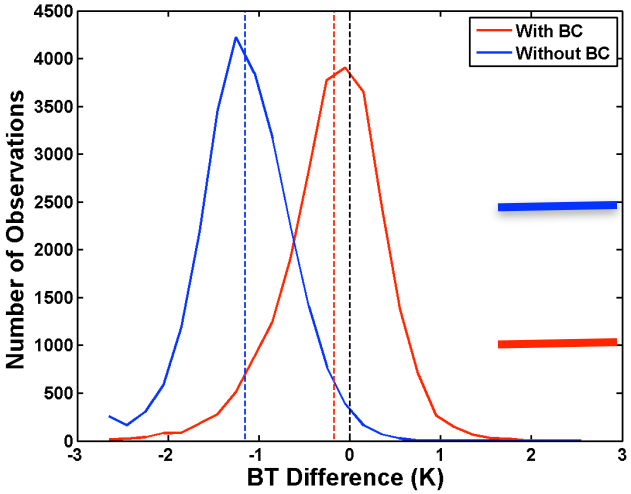


18Z May 29, 2013

Assuming **+/- 1.5 h** time window

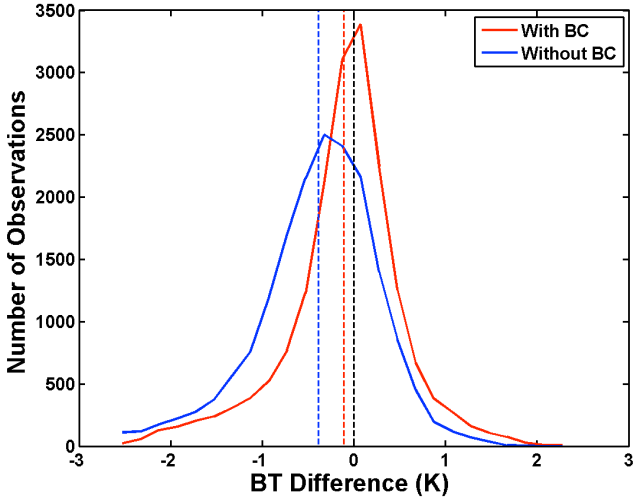
AMSU-A channel 3 from NOAA_18

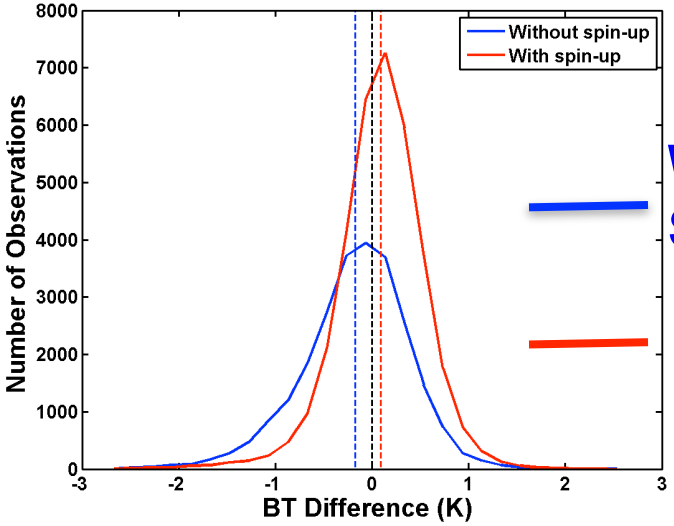
AIRS Bias Correction Assessment



Before BC

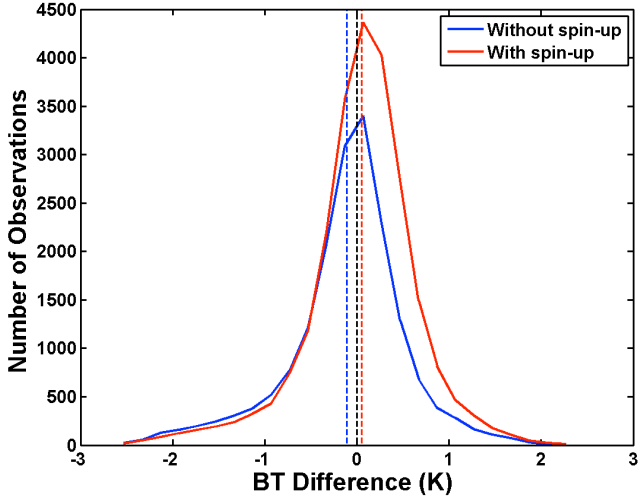
After BC





Without BC Spin-up

With BC Spin-up



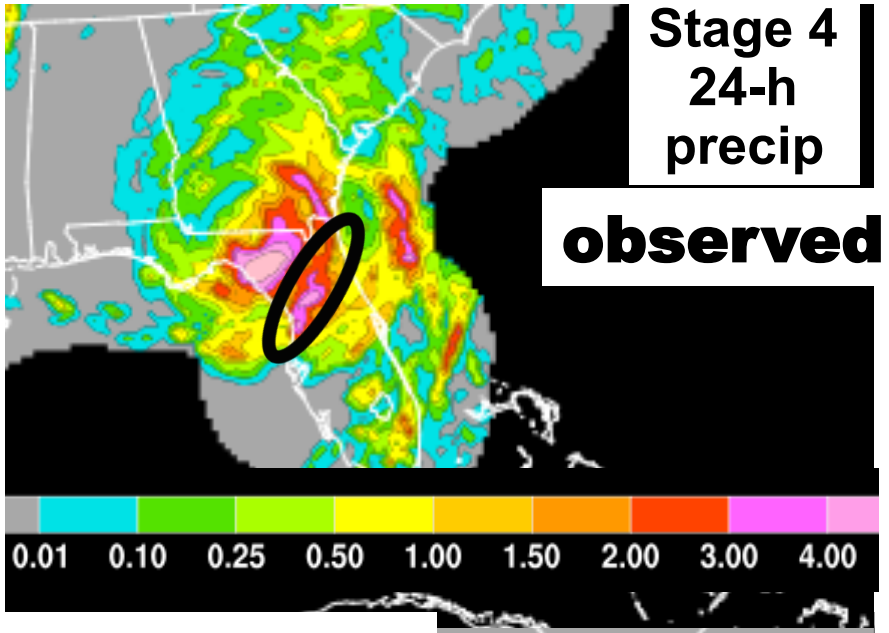
channel 252 (CO2 channel ~672h Pa

Channel 1382 (water vapor channel ~866 hPa

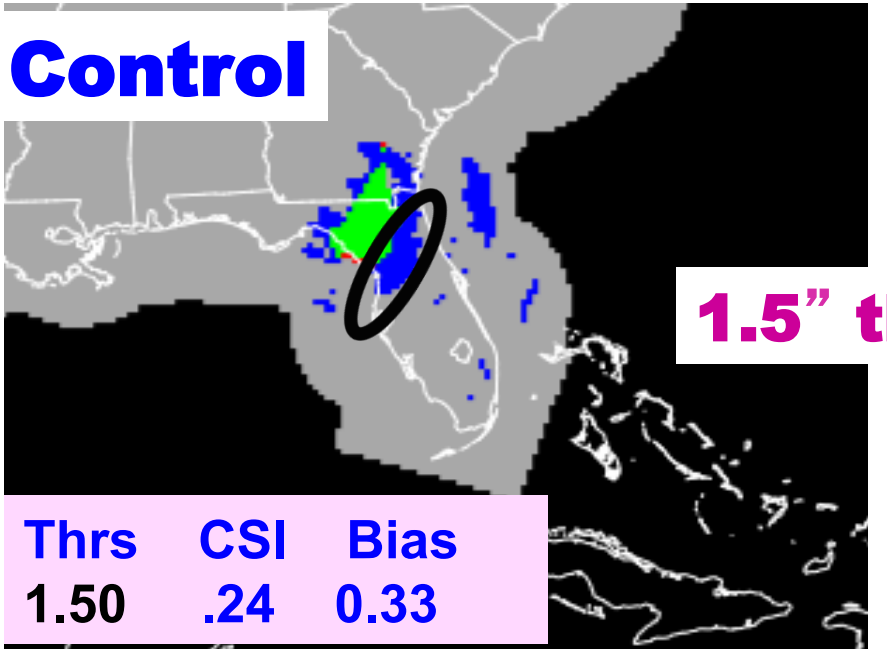
Precipitation Verification

Control vs. Radiance (RARS included)

2 x 12h fcst ending 12z 29 May 2012



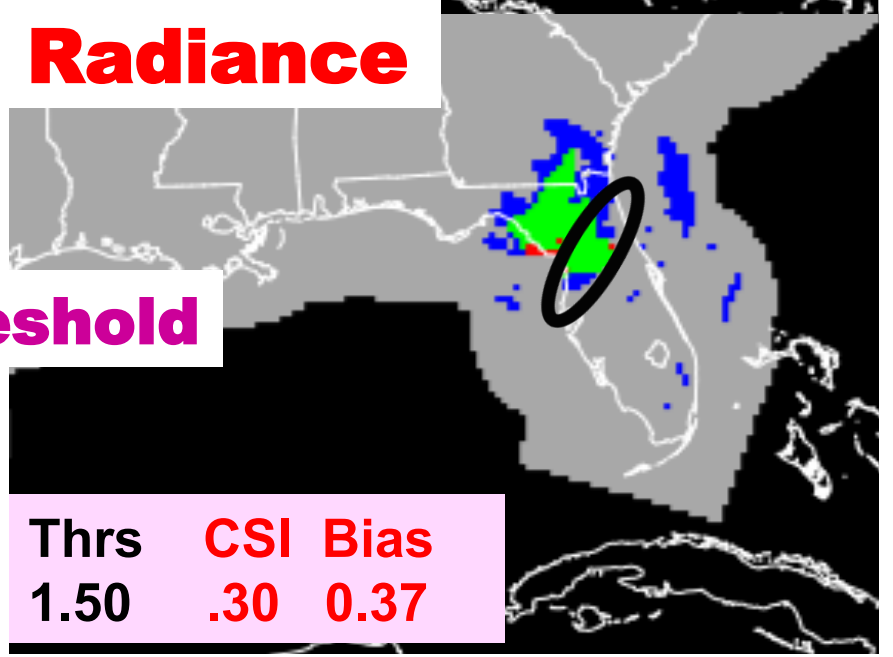
Control



Thrs	CSI	Bias
1.50	.24	0.33

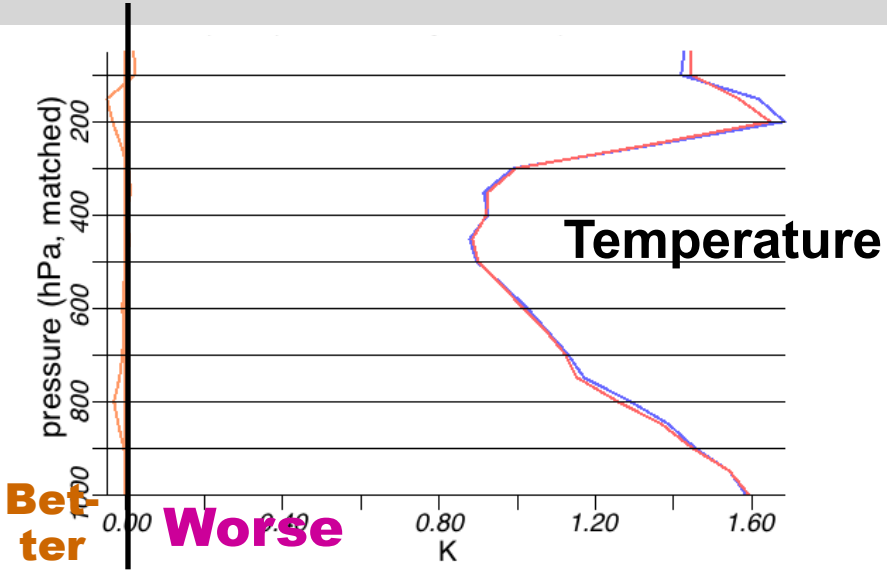
1.5" threshold

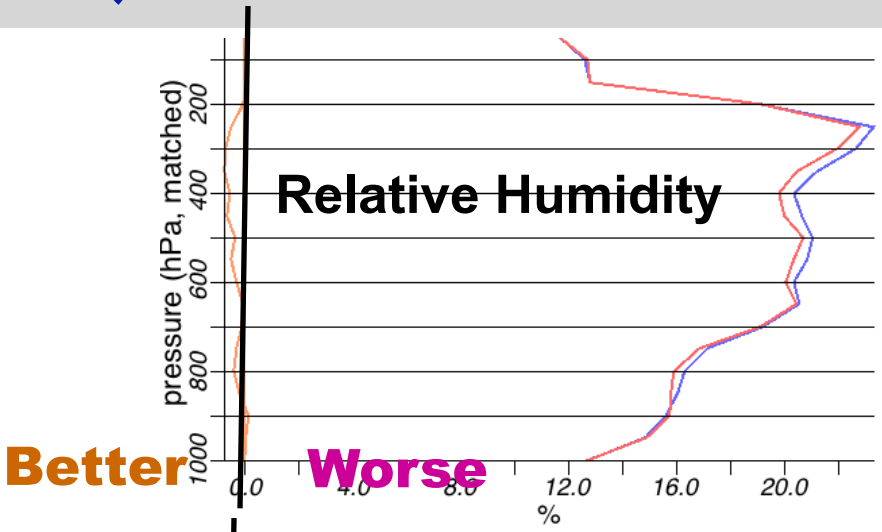
Radiance

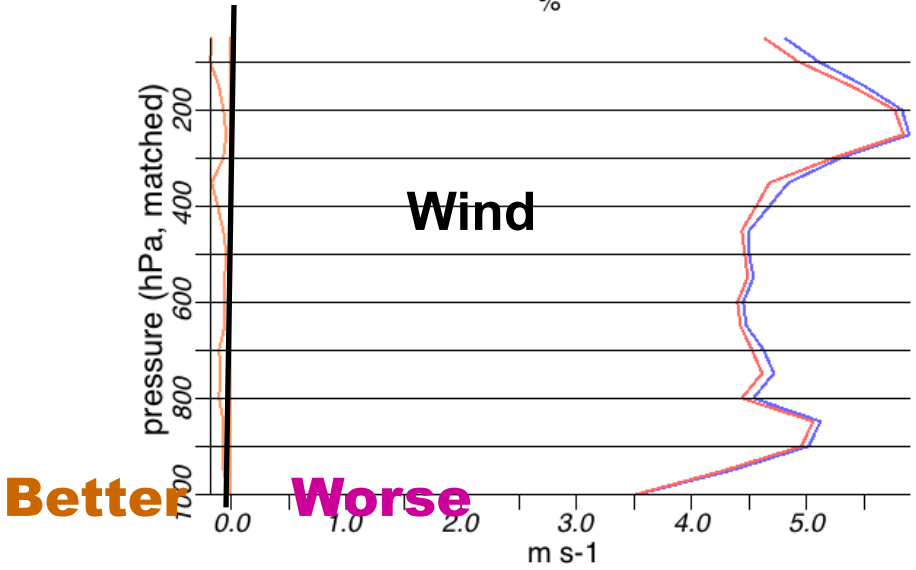


Thrs	CSI	Bias
1.50	.30	0.37

6-h Forecast RMS Error (against raob)







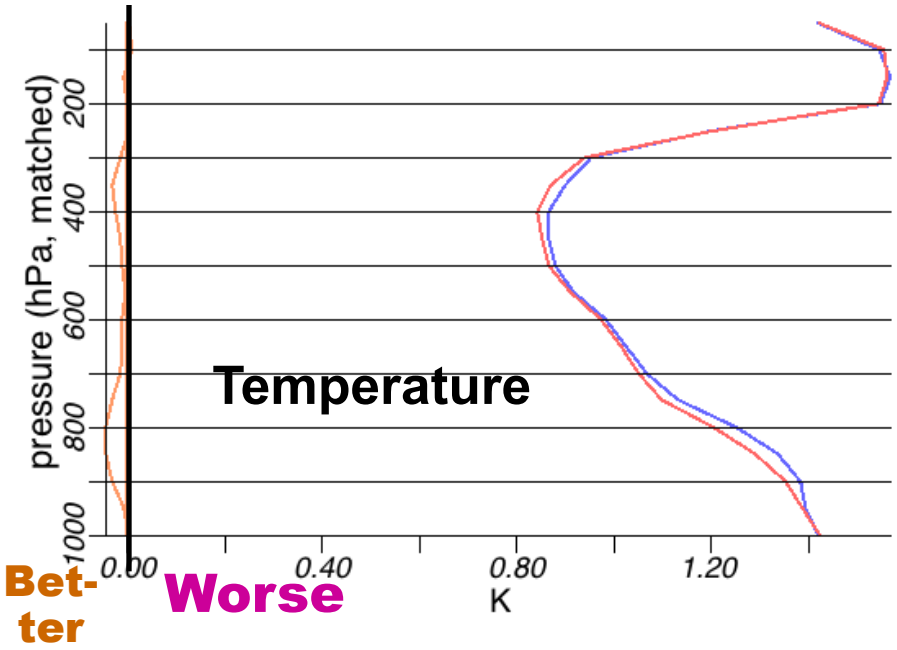
CNTL

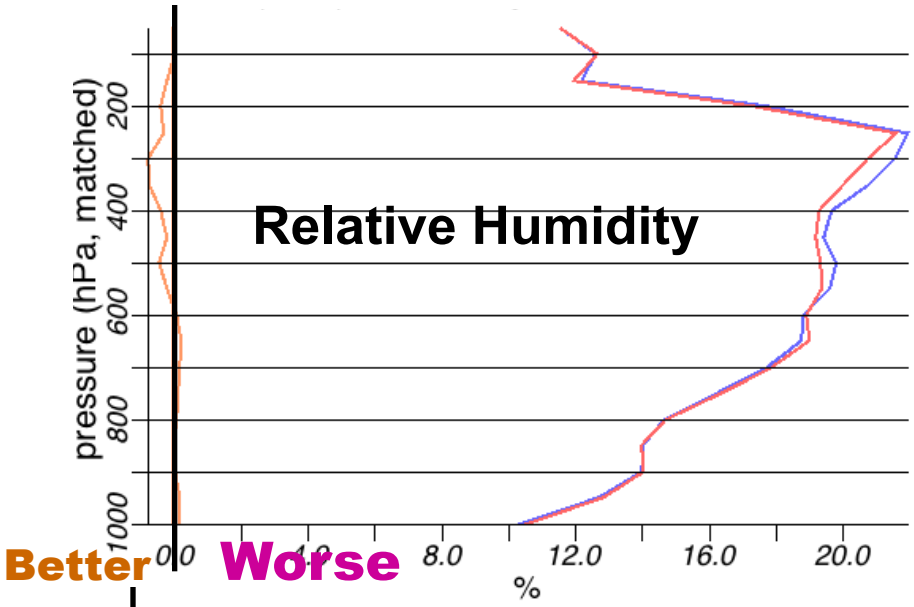
Satellite experiment one (real-time radiance data)

upper-air verification

May28-June04 2012

3-h Forecast RMS Error (against raob)



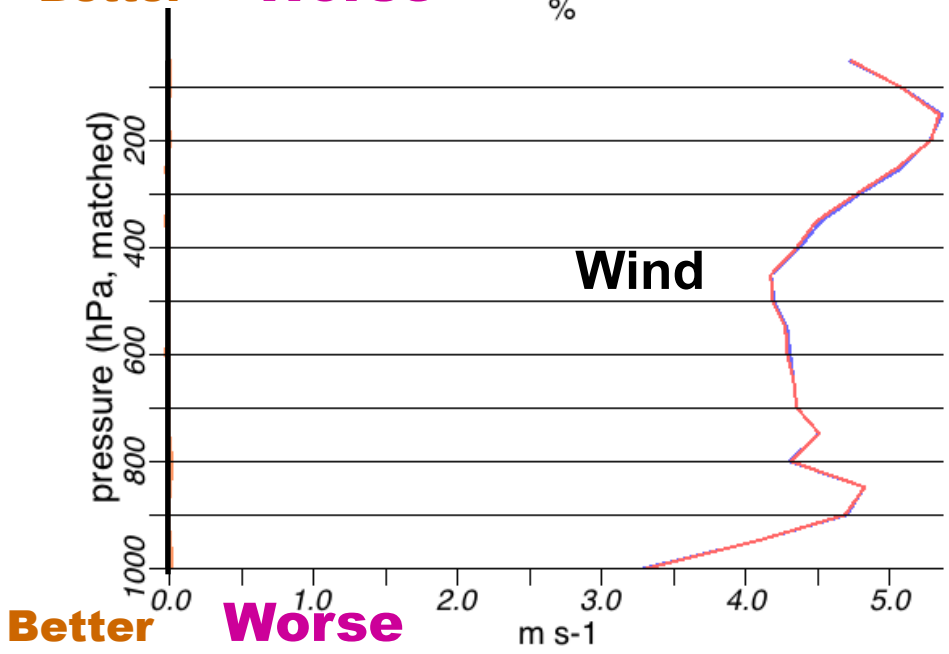


CNTL

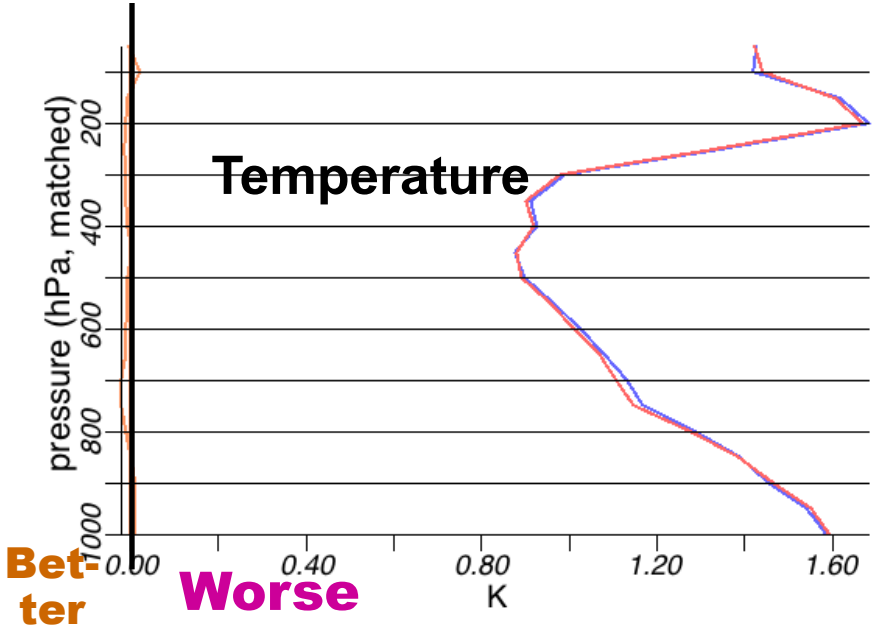
AIRS

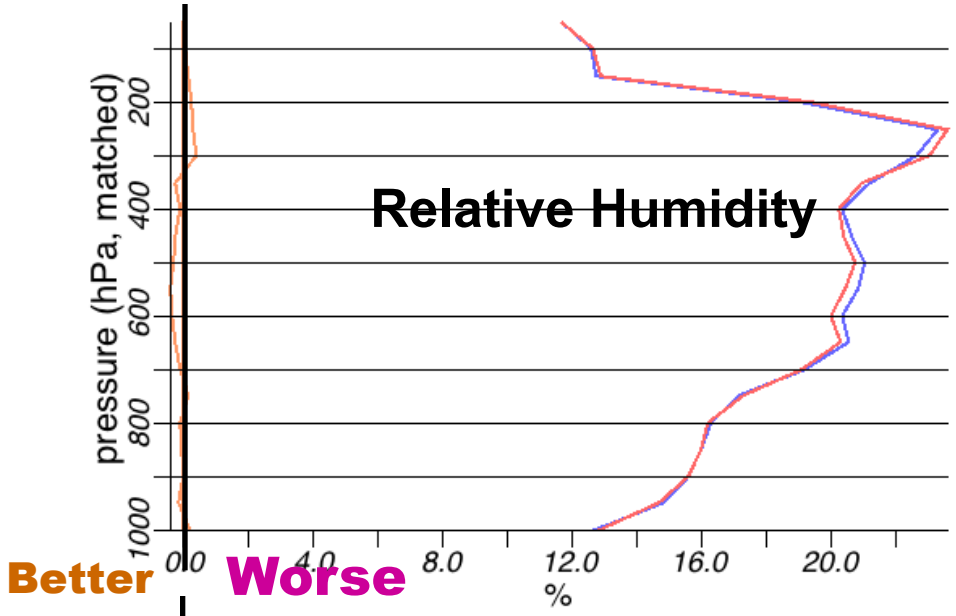
upper-air verification

May28-June04 2012



6-h Forecast RMS Error (against raob)





CNTL

GOES

upper-air verification

May28-June04 2012